Comparative study on treatment of wastewater from brewery industry using Microbial reactors- A comprehensive review

Short review

The treatment of brewery wastewater involves a series of processes that aim to remove pollutants and contaminants from the wastewater generated by brewery operations before it can be discharged into the environment. Brewery wastewater can contain high levels of organic matter, suspended solids, and other pollutants that can harm the environment if not properly treated. The treatment process may involve physical, chemical, and biological methods or a combination of these methods. Some of the common treatment steps for brewery wastewater include:

1. Screening or pre-treatment: The wastewater is screened to remove large solids such as grains, hops, and other debris before it can enter the treatment process.
2. Primary treatment: The wastewater is settled in a primary sedimentation tank to remove suspended solids and heavy organic matter.
3. Secondary treatment: The wastewater is then subjected to biological treatment using microorganisms to further break down organic matter and reduces the concentration of pollutants in the wastewater.
4. Tertiary treatment: Additional treatment processes such as filtration, disinfection, and nutrient removal may be required to remove any remaining pollutants and prepare the wastewater for safe discharge or reuse.

The specific treatment process for brewery wastewater can vary depending on the characteristics of the wastewater and the discharge regulations in the area. However, the goal is to ensure that the treated wastewater meets regulatory standards and is safe for discharge into the environment or for reuse. Microbial reactors can play an important role in the treatment of brewery wastewater. Brewery wastewater contains a high amount of organic matter, including sugars, proteins, and other compounds that can be degraded by microorganisms. Microbial reactors provide a controlled environment for microorganisms to grow and metabolize these compounds, which can help to break down the organic matter and remove pollutants from the wastewater. Microbial reactors can be a cost-effective and sustainable way to treat brewery wastewater, as they provide a natural, low-energy solution for pollutant removal. Additionally, the use of microbial reactors can help to reduce the environmental impact of brewery operations, as the treated wastewater can be reused for non-potable uses like irrigation or released into the environment safely. This process involves using specialized reactors that provide an environment for the growth and metabolism of microorganisms that can degrade the organic and inorganic pollutants in the wastewater. Microbial reactors can be designed in various configurations, including anaerobic digestion and aerobic bioreactors, to treat brewery wastewater. In anaerobic digestion, the organic matter in the wastewater is broken down by microorganisms without oxygen, resulting in the production of biogas as a byproduct. On the other hand, in aerobic bioreactors, microorganisms decompose the organic matter in the presence of oxygen, producing carbon dioxide and water as byproducts. By using microbial reactors to treat brewery wastewater, the pollutants in the wastewater can be reduced or eliminated, allowing the treated wastewater to be repurposed for non-potable uses like irrigation or safely released into the environment. Additionally, microbial treatment of brewery wastewater can be a sustainable and cost-effective solution for managing and reducing the environmental impact of brewery operations.

Tamang et al. [1] investigated the use of microbial mixed cultures (MMC) for producing polyhydroxyalkanoates (PHA) from brewery wastewaters. They enriched MMC with PHA-accumulating bacteria and tested different feeding strategies that make use of anaerobically treated and acidified brewery wastewaters, such as adding pulse and batch feed. The study found that the pulsed addition of acetate, which was controlled by the dissolved oxygen concentration, enabled the enriched MMC to accumulate up to 72.6% of the cell's dry weight (CDW), and produced similar levels of PHA when fed with both wastewaters. These findings suggest that MMC could be a promising approach for the sustainable management of brewery wastewater while producing valuable bio products.

Jia et al. [2] investigated the utilization of conductive carbon cloth as a supporting material in an AnDMBR for the wastewater treatment of breweries. The purpose of the study was to see if using carbon cloth would enable higher organic loading rates than using polyester cloth that did not conduct electricity. Even when fed high concentrations of influent COD (10,000 mg/L), the AnDMBR with carbon cloth performed reliably and demonstrated a removal efficiency of 98 percent for chemical oxygen demand (COD). In contrast, when only 5000 mg/L influent COD was fed to the polyester cloth reactor, it began to deteriorate. Microorganisms capable of direct interspecies electron transfer (DIET), such as Geobacter and Methanothrix species, dominated the carbon cloth's surface, according to the study. This suggests that carbon cloth is an excellent support for AnDMBR because it encourages the development of microorganisms that are capable of directly transporting electrons between conductive materials and one another. Overall, the use of carbon cloth in AnDMBR has shown promising results for the treatment of brewery wastewater at high organic loading rates. The study highlights the importance of selecting appropriate supporting materials for AnDMBR and the potential benefits of conductive materials in enhancing the performance of anaerobic treatment systems.

Al-Mohammedawi et al. [3] used Rhodobacter sphaeroides 158DSM in a batch bioreactor to investigate the effect of pre-treating brewery wastewater with banana peels on photofermentative hydrogen production.

The findings demonstrated that the cumulative hydrogen production significantly increased when banana peels were used to pre-treat the wastewater. When the substrate was 50 percent standard medium and 50 percent brewery wastewater that had been pre-treated for two hours with 1 g L-1 of banana peels, the highest yield of hydrogen production was achieved (408.33 mL H2 L-1 wastewater). Compared to using raw brewery wastewater as the substrate source, the study found that the use of pre-treated wastewater resulted in 2.7times higher hydrogen production. These findings suggest that pre-treating brewery wastewater with banana peels could be an effective way to improve the efficiency of photofermentative hydrogen production using Rhodobacter sphaeroides 158DSM, which important implications for the development of sustainable and renewable energy sources.

Akbarzadeh et al. [4] developed a sustainable "waste plus waste to hydrogen" method for both hydrogen production and simultaneous treatment of waste from magnesium and brewery industries through hydrolysis. The addition of acetic acid at varying concentrations accelerated the hydrolysis of magnesium scraps in brewery wastewater, leading to successful reduction of persistent pollutants and a 62.4% reduction in COD. The highest hydrogen generation was achieved with 30 wt% acetic acid, with a yield of over 60% in just 5 minutes. This eco-efficient approach provides a promising method for waste treatment and hydrogen production without the need for additional energy consumption.

Chen et al. [5] conducted an analysis of the bacterial community structure in an internal circulation (IC) reactor with varying heights for large-scale wastewater treatment in breweries. They discovered that Longilinea, Desulfomicrobium, Caldithrix, Geobacter, and Syntrophorhabdus were relatively common at the genus level, while Proteobacteria, Bacteroidetes, and Chloroflexi were the most common bacteria at the phylum level. Organic fermentation, hydrolysis, and acidification took place primarily at the reactor's bottom, while production of hydrogen and methane took place in its upper and middle sections. The IC reactor was found to effectively remove CODCr and BOD5 from the brewery wastewater. Alpha diversity and cluster distance analysis also showed that the bacterial community could be divided into the lower, middle, and upper parts of the IC reactor.

Asensio et al. [6] have proposed the use of a microbial electrochemical fluidized bed reactor (ME-FBR) that is capable of treating genuine brewery wastewater continuously for a full year. ME-FBR performed better than the conventional anaerobic fluidized bed reactor (AFBR) in resilience tests when simulating typical operational issues real brewery wastewater treatment plants, including high pollutant loads, the presence of biocides, long periods of starvation, and low temperatures. ME-FBR exhibited superior performance in terms of the COD removal rate, total nitrogen removal rate, and bioenergy recovery through the generation of hydrogen using bioelectrochemical assistance

Schneider et al. [7] investigated the feasibility of using forward osmosis membranes in anaerobic membrane bioreactors (FO-AnMBRs) for the treatment of brewery wastewater while simultaneously producing biogas and recovering water. The study compared continuous stirred tank reactor operation without membranes to the start-up times of two lab-scale FO-AnMBRs fed with real and synthetic brewery wastewater. The integration of membranes resulted in a nine-fold increase in CH4 production in both reactors, demonstrating the potential of FO-AnMBRs for the treatment of brewery wastewater. However, due to shear stress and an inadequate C/N ratio in the wastewater, process stability decreased with decreasing hydraulic retention time (HRT).

Negassa et al. [8] investigated the use of double chamber microbial fuel cells (MFCs) for producing bioelectricity and treating wastewater from breweries simultaneously with microorganisms isolated locally. The microorganisms came from food processing industry waste sludge, brewery wastewater, and brewery waste sludge. With a maximum power density of 0.8W/m3 using synthetic wastewater and 0.35W/m3 using actual brewery wastewater, the MFCs inoculated with microorganisms from brewery waste sludge performed the best. The locally isolated microorganisms successfully removed 79-83% of COD, demonstrating the potential of MFCs for sustainable and clean energy production through the treatment of brewery wastewater.

Khumalo et al. [9] studied the use of an anaerobic-aerobic sequencing batch reactor (SBR) that uses activated sludge to get rid of COD and orthophosphates from brewery wastewater. Orthophosphates were removed at 69% and total COD at 54%, respectively, with a sludge retention period of 7 days and hydraulic retention period of 18 hours at a mesophilic temperature of 25°C. For orthophosphate removal, the SBR system remained stable across a range of SRT and organic volumetric loading rate variations. The experimental results showed a 4-hour anaerobic reaction period and a 14-hour aerobic phase, demonstrating the feasibility of the SBR system for orthophosphate and COD removal with variations in organic loading rate.

Jatto et al. [10] explored three kinetic models and found that the Pseudo-second order model provided the greatest compatibility for treating wastewater, based on high r2 values for various parameters including pH, temperature, alkalinity, turbidity, electrical conductivity, and various contaminants such as TS, TSS, TDS, BOD, COD, DO, NO3-N, Phosphate, and Sulphate. The study also conducted a comparison of physicochemical parameters between treated and untreated wastewater at various points in time.

The summary of research gaps are given in Table 1.

Table 1 Summary of Research gaps

Ref.	Author/ Year	Motive	Treatment system	Treatment efficiency	Research gaps
[1]	Tamang et al, (2018)	PHA production	Acetate-enriched MMC	Maximum PHA storage capacity (44% CDW)	Susceptible to mechanical breakdowns.
[2]	Jia et al, (2019)	Conductive carbon cloth production	Anaerobic dynamic membrane bioreactors (AnDMBR)	COD removal rate 98%	The effectiveness of the wastewater treatment improves with a longer duration of the wastewater.
[3]	Al-Mohammedawi et al, (2018)	Photofermentative bio-hydrogen Production	Clear glass bioreactor (120mL)	The increase percentage in hydrogen 182%	Bio-filters need to be back washed regularly.
[4]	Akbarzadeh et al, (2020)	Hydrogen generation	Hydrolysis reaction	COD removal rate 62.4%	The transfer of oxygen is not very efficient.
[5]	Chen et al. (2021)	Bacterial community structure analysis	Internal circulation (IC) reactor	COD removal rate 80% - 84.09%	Regulating or managing biomass is a difficult task.
[6]	Asensio et al. (2021)	To study and analyzes the robustness of reactor	Microbial electrochemical fluidized bed reactor (ME-FBR)	COD removal rate 83% and TN removal rate 70%	The presence of a thick biofilm creates a barrier to mass transfer, leading to a reduction in the biofilm's activity.
[7]	Schneider et al, (2021)	Energy-efficient solution for the treatment of brewery wastewater	Anaerobic membrane bioreactors incorporating forward osmosis membranes (FO-	COD removal rate 84%	The occurrence of membrane defects can result in significant disruptions to the process.

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[8]	Negassa et al. (2021)	Generation of sustainable bioelectricity	MFCs with locally isolated microorganisms	COD removal rate 79- 83%	Incapability to eliminate phosphorus.
[9]	Khumalo et al. (2022)	To study and analysis of orthophosphates and COD Removal	Sequencing Batch Reactor	COD removal rate 69%	The process has a restricted degree of flexibility.
[10]	Jatto et al. (2020)	Kinetics studies	Powdered snail shell	COD removal rate 72%	Ineffective removal of nutrients.